भारतीय मानक
Indian Standard

IS 18008 (Part 1) : 2021

स्मार्ट सिटीज — जीआईएस

भाग 1 रेफेरेंस आर्किटेक्चर

Smart Cities — GIS

Part 1 Reference Architecture

ICS: 35.240.70

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June 2021 **Price Group 11**

Smart Infrastructure Sectional Committee LITD 28

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Smart Infrastructure Sectional Committee, had been approved by the Electronics and Information Technology Division Council.

The Composition of the panel, LITD 28/P10 and the sectional committee, LITD 28 responsible for the formulation of this standard is given at Annex B.

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0 INTRODUCTION

0.1 Current Challenges of GIS in Smart Cities

At present, GIS is commonly used as a spatial information and visualisation tool in the existing Smart Cities. The utilisation of this powerful technology varies considerably across cities, often limited by non-availability of base maps and non adaptability of Enteprise GIS Platforms. GIS will play a significant role in spatial decision making in Smart Cities when standards based maps are developed and integrated into routine functioning of the Smart Cities.

Currently, cities are not completely aware about the overall functional requirements of the GIS and the technological architecture of the enterprise wide GIS, which is important for collaborative decision making.

In absence of standards for the GIS layers that need to be adopted, the cities are not able to take the benefits of the Enterprise GIS for the decision making in the cities.

This standard has been developed with the objective of defining the GIS usability for the different stakeholders in smart cities. It provides a conceptual GIS architecture with functionalities to use as an enterprise system for spatial decision making.

To guide the cities in the usability of the GIS, the functional requirements are mentioned.

Lastly GIS application use cases are provided to guide the city in understanding the GIS applicability for the smart city in standardized ways.

This standard has to be read in conjunction with other standards on Smart Cities or Unified Digital Infrastructure such as IS 18000, IS 18002, IS 18004, IS 18006 etc.

Enterprise GIS is an architecture that integrates geospatial data and services and shares them across the organization. It can also be viewed as an infrastructure that extends and enables existing systems using geospatial data and services.

Core to enterprise GIS is the ability to meet organizational objectives through the delivery of geospatial capabilities that include the following:

a) Data management — data management is important in an enterprise setting. Enterprise GIS data management focuses on the efficient storage and retrieval of all of an organization’s relevant geographic information. An enterprise GIS data may be decentralized, with appropriate data management standards and data governance processes defined, so as to ensure that the data integrity is maintained and also the data is available for usage by everyone in the organization.

b) Visualization — The visualization of information in a geographic context provides an intuitive means for accurate and rapid decision making. Visualization is the most obvious manifestation of enterprise GIS, however, enterprise GIS should fully exploit visualization capabilities by incorporating them into tasks and activities not traditionally associated with GIS like e-Governance applications or Business applications or ERP.

c) Spatial analysis — exploiting the wealth of geographic information in an organization is the goal of spatial analysis for the enterprise. Non-traditional users of GIS will benefit from this capability. A key objective of enterprise GIS architects and designers should be the geospatial enabling of other enterprise systems (e.g., IoT applications) with spatial analytical capabilities.

0.2 Key Stakeholder concern

The stakeholders in the current environment of the Smart City involves the Special purpose Vehicle (SPV), the Municipal Corporation, Citizens, Business, Researchers, Operation and Maintenance Team of cities, State Government and Central Government. Table 1 provides a summary of different stakeholders of smart city their business processes and their requirements from a GIS perspective.

Table 1 Stakeholders requirements from GIS perspective in Smart Cities

Stakeholder	Business requirements	GIS Requirement
Municipality	1. City Base Maps including different layers of information like Roads, sewerage network, public bins, street lights etc. 2. Tracking of different projects in the city for construction, maintenance and operations. 3. Strengthening the municipal finance through revenue enhancement and expenditure monitoring. 4. Tracking the performance of different city aspects like pollution, cleanliness, literacy, distribution of healthcare facilities in a ward/locality etc. 5. Covid-19 related Contentment Zone, Vaccination Centre, Covid Center/Hospitals.	1. City Geodata model with defined layers, attributes, relationships and cartography. 2. Common Base maps for all departments to collaborate on decision making. 3. Collect spatial information from various sources and utilise it across the enterprise. 4. Spatial tracking of municipal projects/activities. 5. Spatial tracking of municipal Income and expenditure. 6. Spatial tracking of performance of city as per different parameters. 7. Spatial tracking of all city assets and resources. 8. GIS based mobile app with workflow for field operations in city level. 9. Survey apps to collect the pandamic related data and display as dashboards.
Smart City SPV	1. Planning the smart city in terms of planning, design, construction and operations. 2. Asset Inventory of the smart city and their coverage. 3. Real time tracking of the information flow and access to different spatial layers for a coordinated decision making.	1. Common Base Maps to understand the requirement of different stakeholders of smart city. 2. Municipal Assets inventory required for Smart City. 3. Spatial Area Based Development (ABD) planning. 4. Get the virtual view of the city and urban features and urban problems. 5. Spatial view of Smart City Components (Cameras, GPS enabled Devices, Sensors, IoT devices) with geo-spatial data for smooth operation and monitoring. 6. Real time vehicle tracking, citizen sentiment capturethrough social media integration. 7. Generation of hotspots and analytics of pollution, crime, incidents, events, grievances etc. 8. Geospatial dashboards for decision support system regarding the performance against the benchmarks or thresholds.
Citizens	1. Access to different locational information like the amenities in the neighborhood. 2. Access to different spatial information like Road closure intimation, or traffic jam intimation.Participate in city governance. 3. Raise grievance through mobile Apps using location and geotagged images/photos. 4. Location information related to Pandemic/disease Spread. a Information related to hazards.	1. Means to interact with city through GIS based Web Apps and Mobile Apps, like neighbourhood services. 2. Participation in governance on Development Plans and Smart Developments and different urban issues. 3. Routing services for moving from one place to otherSharing location data and features with different people. 4. Mobile Apps for citizen’s grievance management. 5. Apps to report incident or seak help in the event of Medical outbreak. 6. Integration with Sensors to cover the real time weather and Hard Information for public.
Utility Services	1. Maps for the existing location of the Assets. 2. The demand of services and supply of services. 3. Real time location of the problem areas and quick repair.	1. Common set of base maps for design and construction, operation and maintenance and decision making for utilities like electricity, water, sewerage, storm water drains, street light, piped gas, etc. 2. Utility asset GIS data model to generate inventories of all the assets of the utilities. 3. Spatial asset lifecycle management for understanding age of the asset. 4. Spatial workflow based asset operation and maintenance for addressing the operational problems.
Business	1. Needs locational intelligence for setting up chains, service centers, new business, and branches.	1. Platform to integrate with open socio-economic data like Population density data, socio economic data, administrative boundaries, land use details.

Table 1 (*Concluded*)

Stakeholder	Business requirements	GIS Requirement
Researchers	1. Needs access to spatial and non spatial data related to urban features/problems.	1. Platform to get open GIS data/APIs for conducting spatial research on urban dynamics and issues.
Operation and Maintenance Team of City	1. Needs the details of the City properties and assets. 2. Need location of the problem areas for quick service delivery.	1. Location based workflows for reporting of urban issues and problems like water leakage or potholes on roads. 2. Location based alert generation as a part of spatial workflow. 3. City problem tracking and resolution status. 4. GIS based dashboard for tracking of O & M performance.
State Government	1. Needs to undertake monitoring of the projects progress under the mission cities in the state. 2. Needs to undertake the monitoring of funds utilization and requirement for mission objectives.	1. Monitoring of the Smart Cities projects in the state. 2. Smart City projects tracking Geographically with project management aspects. 3. Smart City fund tracking at state level.
Central Government	1. Needs to undertake monitoring of the projects progress under the mission cities in the country. 2. Needs to undertake the monitoring of funds utilization and requirement for mission objectives.	1. Monitoring of Smart City program progress. 2. Geographic Smart Cities project tracking. 3. Geographic Smart City fund tracking. 4. Smart city projects performance monitoring. 5. Enable gap based knowledge sharing between smart cities.

0.3 Role of GIS in Smart Cities

GIS plays an important role in the complete lifecycle of Smart City, from planning, designing, construction, operation and maintenance to management. Smart city GIS shall integrate with different survey tools, modelling software, different types of sensors and IoT devices, and other e-governance enterprise systems like land management applications, asset management systems etc. for spatial decision support.

a) **Planning and Design of Smart City**: GIS helps to analyse the location of the Assets and Properties in the city and the Gap in the provision as per population, area and distance norms. It helps to analyse the right sites for city development, view legal boundaries, and arrive at a right valuation of the existing or new sites. GIS integrates with different survey technologies like DRONE, Aerial Survey, LIDAR, GPR, etc and may be associated with design tools like Building information modelling (BIM), Computer Aided Design (CAD) for 3D analysis.

b) **Construct**: GIS should integrate with the project management and financial management systems and tools for construction monitoring of the different smart city projects.

c) **Operation and Maintenance**: GIS based asset Maintenance system create the models of all the assets and properties in the city for their maintenance, repair and refurbishment, real time update of functioning by integrating with SCADA, Smart Metering, Remote Transmission Unit (RTUs) etc and field operation management.

d) **City Expansion Plan**: This is important especially for the Green field Smart cities to create the land banks and inventory of infrastructure to attract buyers, tenants, business. *Analyze* demographics and market conditions to provide a more accurate picture of a property's suitability to needs.

e) **City Insights:** The GIS helps in the city management by creating intelligence of spatial distribution, collaborated operation and maintenance, dynamic real time dashboards about city functions, city economics (revenue and expenditure) and performances.

Fig. 1 describes the City functions, how GIS technology and tools can help the city in undertaking the functions and the outcomes of the technology application.

While defining the role of GIS in smart city, the following fundamental concepts should be taken care of:

a) Standardization: Standardization of urban processes, mobility and logistics, safety and security, information and communication, energy uses, and production etc.

b) Integration: integration of the different data system, processes, operational workflows, and real-time information.

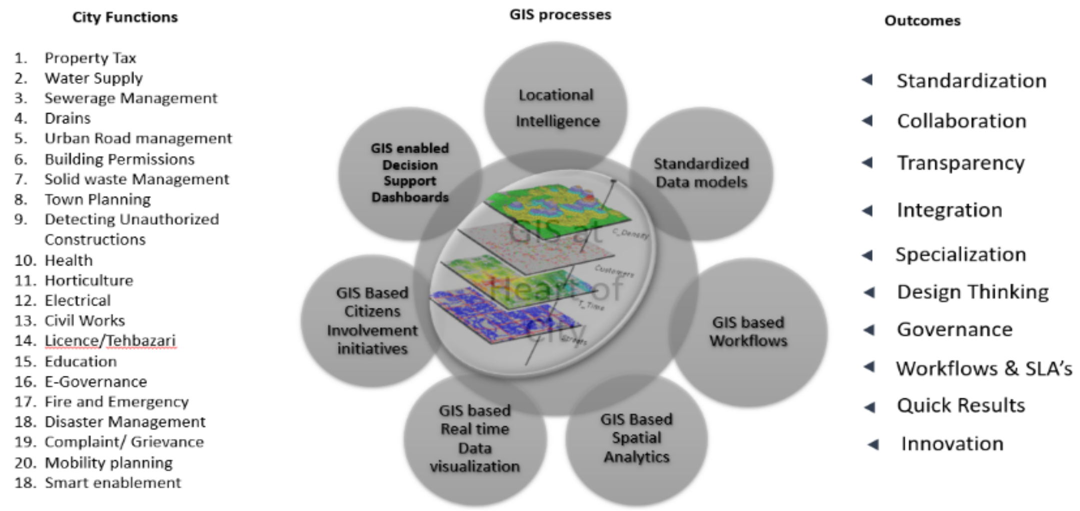

FIG. 1 CITY GOVERNANCE ASPECT AND GIS AT CORE

c) Design thinking: Design thinking is an analytical and creative approach that focuses on the concerns, interests and values of the user. In the city's case, the user could be the citizen, the entrepreneurs, the academia and researchers, the builders and urban service providers.

d) Collaboration: collaboration should be across municipal departments, line departments, emergency services, businesses and NGOs, and most importantly, citizens. As an integral part of smart cities, citizens shall help public authorities to work more efficiently together by integrating citizen-sourced data from smart city apps, as well as individually reporting incidents or flagging concerns.

e) Innovation: City innovation in management, policy and technology. Since the unique context of each city shapes the technological, organizational and policy aspects of that city, a smart city can be considered a contextualized interplay among technological innovation, managerial and organizational innovation, and policy innovation.

Indian Standards

SMART CITIES — GIS

PART 1 REFERENCE ARCHITECTURE

1 SCOPE

This Indian standard describes the Enterprise GIS reference architecture that comprises the functional architecture, technical reference model, and information reference model of the enterprise GIS. It also specifies the core capabilities and key design principles of the enterprise GIS.

The implementation methodologies and deployment architecture of the GIS are excluded from the scope of this standard.

2 REFERENCES

The standards given below contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of these standards.'

IS 18000 Unified Digital Infrastructure — ICT Reference Architecture.

3 TERMINOLOGY AND ABBREVIATIONS

3.1 Terminology

For the purpose of this standard, the following shall apply.

3.1.1 *Coordinate System*

A reference framework consisting of a set of points, lines, and/or surfaces, and a set of rules, used to define the positions of points in space in either two or three dimensions. Cartesian coordinate system and the geographic coordinate system used on the earth's surface are common examples of coordinate systems.

3.1.2 *Datum*

The reference specifications of a measurement system, usually a system of coordinate positions on a surface (a horizontal datum) or heights above or below a surface (a vertical datum).

3.1.3 *Digital Elevation Model*

The representation of continuous elevation values over a topographic surface by a regular array of z-values, referenced to a common datum. DEMs are typically used to represent terrain relief.

3.1.4 *Geocode*

A geocode is the set of latitude and longitude coordinates of a physical address.

NOTE — It can be done by plotting x,y (lat, long) data.

3.1.5 *Geocoding*

Geocoding is the process of turning a physical address into a set of latitude and longitude coordinates which can then be plotted or displayed on a map.

3.1.6 *Geoevents*

Geo Events are data in an event stream in order for an Input Connector to construct a Geo Event from the events coming in, like disaster event, accident event, pipe breakage etc.

3.1.7 *Geospatial Data*

A database or file structure used primarily to store, query, and manipulate spatial data. Geo Spatial databases store geometry, a spatial reference system, attributes, and behavorial use data. Allows you to store many different data in one packaged file, rather than many spatial data associated files in a simple folder. Certain operations seem to run more smoothly when your data is packaged in a geospatial database.

3.1.8 *Georeference*

An operation in which an image (such as an aerial photo/satellite image/radar images/scanned maps) is aligned to a known coordinate system so it can be viewed and analyzed with other spatial data. Typically, georeferencing involves overlaying an image above a basemap and aligning known points on the image with the basemap (such as an easily identifiable street intersection).

3.1.9 *Global Navigation Satellite System (GNSS)*

A standard generic term for satellite navigation systems that provide autonomous geo-spatial positioning with global coverage. This term includes e.g. the GPS, GLONASS, Galileo, Beidou, NAVIC and other regional system like IRNSS of India.

3.1.10 *Enteprise GIS*

The implementation of GIS infrastructure, processes and tools at scale within the context of an organization, shaped by the prevailing information technology patterns of the day. Enterprise GIS is integrated into, and shaped by the business processes, culture and context of an organization.

3.1.11 *Layer*

The visual representation of a geographic dataset in any digital map environment. Conceptually, a layer is a slice or stratum of the geographic reality in a particular area, and is more or less equivalent to a legend item on a paper map. When spatial data (such as a shapefile, MIF, KML, GML or similar) is added to a GIS application it is represented as a layer on a map.

3.1.12 *PAN Images*

Single channel (panchromatic) image producing better ground resolution.

3.1.13 *Raster Data*

A spatial data model that defines space as an array of equally sized cells arranged in rows and columns. Think of these cells as pixels.

3.1.14 *RESTFUL APIs*

An architectural style for an application program interface (API) that uses HTTPs requests to access and use data. That data can be used to GET, PUT, POST and DELETE data types, which refers to the reading, updating, creating and deleting of operations concerning resources.

3.1.15 *Shapefile Or shp*

This is the Open File format for geographic or spatial data.

NOTE — Shapefile is the most frequently used file type in GIS. Shapefiles appears as points (placemarks, cities etc), lines (roads, rivers etc), or polygons (state boundaries, counties, zones).

3.1.16 *SOA Architecture*

Software architecture consisting of coupled services. Service-oriented architecture, defines a way to make software components reusable and interoperable via service interfaces.

3.1.17 *Topology*

The spatial relationships between connecting or adjacent features in a geographic data layer (for example, arcs, nodes, polygons, and points). Topological relationships are used for spatial modeling operations that do not require coordinate information. Think of it as the relationships between things that are adjacent or connected to one another.

3.1.18 *Vector Data*

A coordinate-based data model that represents geographic features as points, lines, and polygons.

3.2 Abbreviations

API	Application Programming Interface
DEM	Digital Elevation Model
DRONE	Dynamic Remotely Operated Navigation Equipment
GCP	Ground Control Points
GIS	Geographical Information System
GPS	Global Positioning System
GPR	Ground Penetrating Radar
HRSI	High Resolution Satellite Image
IoT	Internet of Things
LIDAR	Light Detection and Ranging
OGC	Open GIS Consortium
UTM	Universal Transverse Mercator

4 GIS DESIGN AND ARCHITECTURE

4.1 Key Design Principle

Enterprise GIS is a system that is integrated through an entire organization so that a large number of users can manage, share, and use spatial data and related information to address a variety of needs, including data creation, modification, visualization, analysis, and dissemination.

Fig. 2 describes the enterprise GIS concept, there are authoritative content creators in an enterprise given the right through enterprise user management. These contents may be shared over web as maps and data, base maps. The contents may be accessed anytime anywhere, using desktops, internet, mobiles, tablets etc. The workflows may be created, through which the field crew can access the alerts and map information and undertake the task.

In addition to the properties described in **7** of IS 18000 : 2020, The enterprise GIS shall adhere to the Key Design Principles given in **4.1.1** to **4.1.5**.

4.1.1 *Scalable*

The solution architecture shall provide the capability to scale the system to meet future needs of additional functionalities and usage without inherent bottlenecks when supported with appropriate infrastructure and licenses. GIS capabilities should offer seamless integration. The solution should be scalable to support minor functional changes or integration through standard interfaces.

4.1.2 *Secure*

The architecture shall be *design*ed to secure data from unauthorized access, modifications, and manipulation

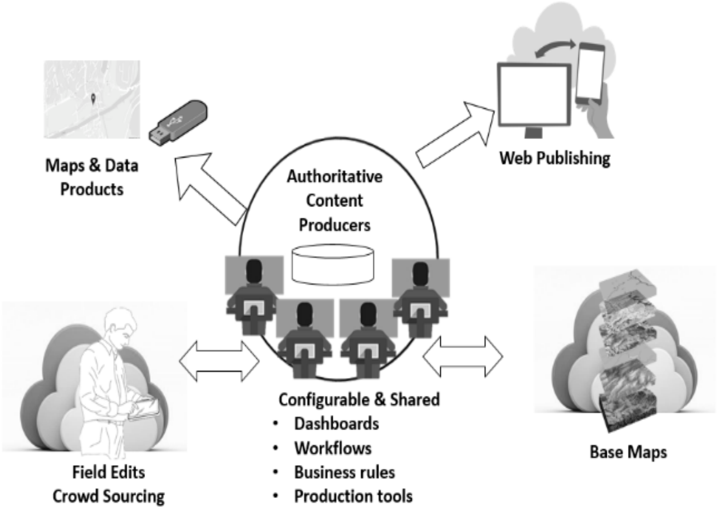

FIG. 2 ENTERPRISE GIS

using advanced user and access management tools and capabilities. It should follow and support security, authentications and authorization including Web tier authentications (for example *IWA,* PKA), GIS tier authentications (Built in identity), Enterprise logins (*for example* SAML 2.0), Enterprise groups (for example Active directory and LDAP) etc.

4.1.3 *High-Availability*

The proposed architecture shall have the capability to be up and running over long periods to ensure availability. Web GIS server should support deployment cluster environments: Active-Active, Active-Passive. There should be flexibility for deploying the solution on premises, on cloud and hybrid architecture.

4.1.4 *Standard Based*

The integration architecture shall be open, interoperable and standard based, so that it ensures a seamless integration with all city services. The proposed Enterprise GIS architecture should support open geo-spatial consortium (OGC) and open web services such as WMS, WFS, WCS, WMTS, WPS, KML, GeoJson & I3S or OGC 3D Tile service for 3D rendering. GIS system shall follow the open service-oriented architecture (SOA). The complete system should be developed using standard development tools. The technology must be based on open standards that can be exchange information with others and able to consume and expose services and API's as per the business needs. The software should provide open API & SDKs for developers to build/extend custom web mapping applications. (ex: Qt, NET, Java, JavaScript, etc).

4.1.5 *Modularity*

The entire design of the integrated solution shall be modular. All the business processes and sub-processes shall structure in a modular way so that any changes, modifications, additions or deletions of any process do not affect the entire flow of the application. The solution shall design to easily accommodate business process changes through Change Management.

4.2 Enterprise GIS – Capabilities and Functional Architecture

Functionally the enterprise GIS system shall provide the following capabilities:

a) **Base Maps**: Common set of Base Maps, over which the city functions can collaborate for a spatial decision support system. The Base Maps can be topographical, satellite image, street maps etc. on which different layers of information can be georeferenced, like property, land use, water supply etc.

b) **Data ingestion from different sources**: Government Data bases, Open Data Portal, Enterprise systems, sensors, e-Governance applications, Survey Tools like GPS, Drones, GPR, LIDAR, REST APIs etc.

c) **Analysis**: It shall facilitate different types of trend and pattern base analysis, generating hotspots, concentration and dispersion patterns, interpolations, statistical models, what-if modelling and predictive modelling may be undertaken.

d) **Workflows**: Location based workflows to generate alerts with locational intelligence and dashboards for status monitoring. The Enterprise GIS shall allow to create dynamic dashboards for monitoring and evaluation, Enterprise GIS shall enable user specific Web Apps and Maps.

e) **Visualization and Dashboards**: Creation of workflow enabled and dynamic dashboards for monitoring, tracking and performance analysis of different smart city segments against thresholds and benchmarks. Enterprise GIS shall facilitate visualization of assets above the ground, below the ground, patterns in 2D and 3D along with Panoramic images.

Annex A describes a set of Use cases enabled by Enterprise GIS within the context of Smart Cities.

Fig. 3 depicts the functions of enterprise GIS through different GIS tools. It provides layers of base maps, described in the GIS information model which may be accessed by different functions, like smart street lights, ERP and e-governance for property and urban services, citizen service Apps, ITS/ITMS etc. Different Enterprise GIS Tools of Live streaming, Analysis, Trends, Patterns, Workflows, Dashboards, Apps and Maps, helps in generating desired thematic and spatial information, which may help in spatial decision support system.

4.3 Enteprise GIS functional reference model

The Enteprise GIS functional reference model comprises different tiers. The tiers are represented in Fig. 4, as to how it integrates with the command and control center.

a) **Data Layer**: Spatial data and Non-Spatial data are foundation layers of Smart Cities. With Georeferencing and topology, the Spatial and Non-spatial data will speak to each other. This shall be integrated into the defined GIS informational model, with defined rules based associations, cartography and schema.

b) **Sensor Layers**: The Sensor Layers feed the data to the GIS system through REST APIs or OGC standards. The sensors provide three types of data to the GIS that are static positions, mobile positions, and geo-events.

c) **Application Tier**: The GIS Application Tier is capable of Geo-processing the data and generating different types of thematic information and statistical analytics. It shall help the cities in generating spatial queries, spatial models, trends and patterns based on data storages from devices and sensors.

d) **Business layers**: The GIS business layer provides information like locational intelligence, as a summary of data, proximity, buffering; hotspots of traffic, events and incidents, real-time vehicle tracking, web applications for waste generation spatial analytics and routing, GIS based dashboards for revenue and tax management, different workflow oriented dashboards for alerts and operation and performance monitoring and GIS based grievance management.

The complete system may adopt different models – on premise, cloud or a hybrid cloud model, whereby the data may be residing *on* the premise servers and analysis may happen on the cloud.

The security of the GIS system should be maintained at the data level, application level and network level.

4.3.1 *Detailed Functional Capability of the Enterprise GIS System for Smart Cities*

Table 2 presents the functional capability of the enterprise GIS system of the smart city, which shall enable the smart cities to seamlessly integrate spatial data from different sources and non spatial data from devices and systems for a spatial decision support system.

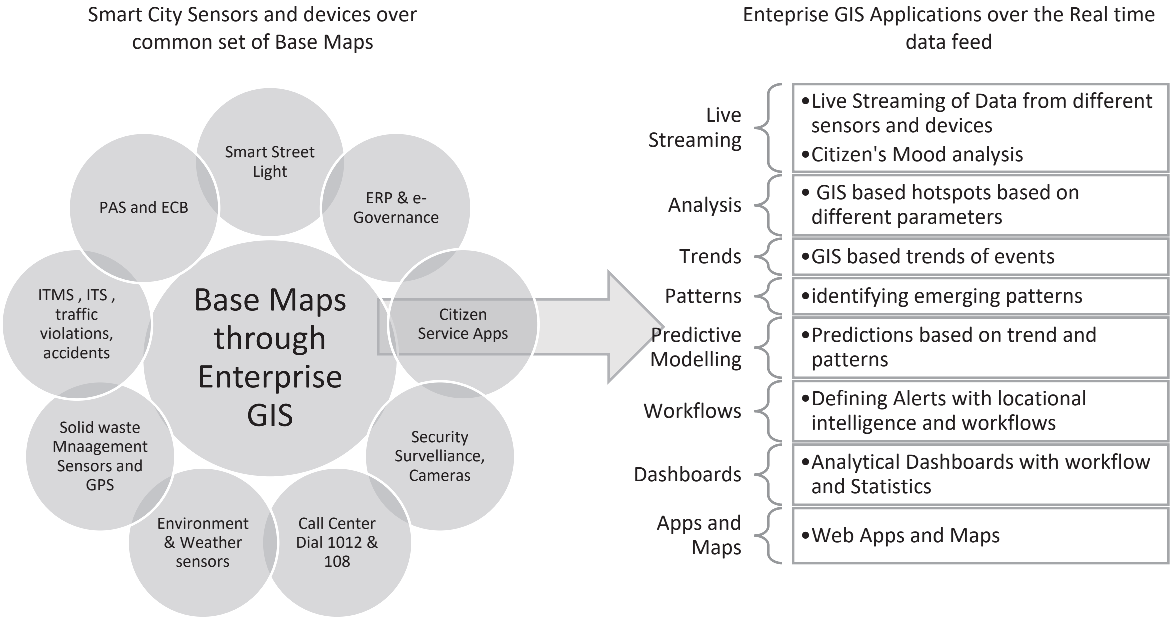
Smart City Sensors and devices over common set of Base Maps
Enteprise GIS Applications over the Real time data feed
Base Maps through Enterprise GIS
Smart Street Light
ERP & e-Governance
Citizen Service Apps
Security Survelliance, Cameras
Call Center Dial 1012 & 108
Environment & Weather sensors
Solid waste Mnaagement Sensors and GPS
ITMS , ITS , traffic violations, accidents
PAS and ECB
Live Streaming
•Live Streaming of Data from different sensors and devices
•Citizen's Mood analysis
Analysis
• GIS based hotspots based on different parameters
Trends
•GIS based trends of events
Patterns
•identifying emerging patterns
Predictive Modelling
•Predictions based on trend and patterns
Workflows
•Defining Alerts with locational intelligence and workflows
Dashboards
•Analytical Dashboards with workflow and Statistics
Apps and Maps
•Web Apps and Maps

FIG. 3 CONCEPTUAL MODEL OF GIS TOOLS FOR SPATIAL DECISION SUPPORT SYSTEM

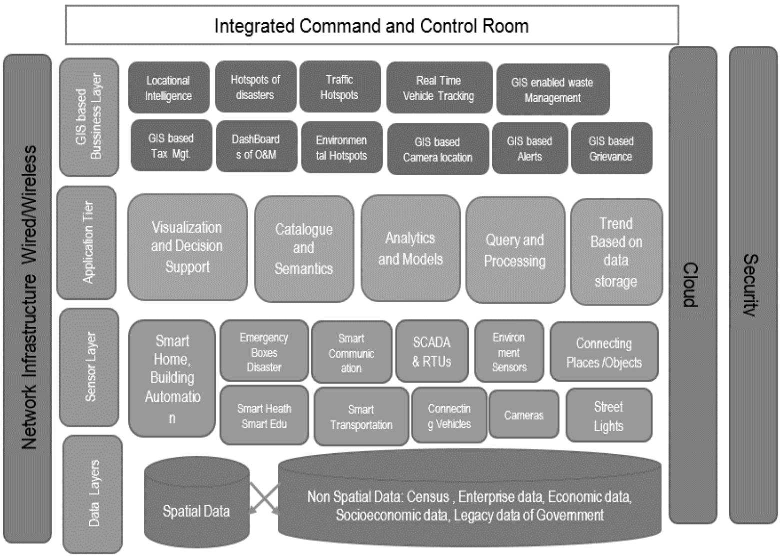

FIG. 4 ENTERPRISE GIS FUNCTIONAL ARCHITECTURE MODEL FOR INTEGRATED ICCC

Table 2 Functional Capabilities of Enterprise GIS for Smart Cities

Sl. No	Capability	Functional Description
F1	**Data Creation and Geo spatial data modelling – Authoring Tools**	
1	Multithreaded architecture of Data and Parallel processing	Desktop GIS System shall run as a native 64-bit application and shall support windows 64-bit architecture.
2	2D-3D Conversion	1. There should be a provision to convert between 2D and 3D. 2. GIS data creation should support 3D city modelling for smart city planning, should support in creation of realistic 3D context and should be able to share these various planning environments on the web browser.
3	Base Maps	It shall support usage of Base Map as Web Services.
4	Raster to Vector and Vector to Raster Conversion	The Desktop GIS should support Conversion of Raster Data into feature data containing Vector-based data.
5	Interoperability Support	It shall support BIM & KML Image Files, interoperability support, LIDAR classification, feature extraction and editing.
6	Animation of 3D views	1. Functionally GIS should facilitate animation to 3D views and able to export video out of it with predefined bookmarks or presentations. 2. On the fly automatic labelling, multi-labelling, interactive labelling, rotation of labels from an attribute field, interactive label placement, predefined label styles & finally saves labels as a data layer, for analytics and anoytion in Smart City GIS data.
7	Geoprocessing and Editing history	There shall be geoprocessing and editing history for testing and/or audit purpose. Version management shall be there in the data model for regular GIS update and archiving old data.
8	Network Modelling	There shall be tools for building network data with Multipoint routing ability for shortest route, driveway, safest route analysis.
9	Proximity analysis	There shall be tools for the identification of the closest facility. Provision for creation of an origin to destination matrix on map. This shall support neighbourhood analysis.
10	Routing and Geofencing	It shall have the facility to share a route layer including all the information for a particular route such as the stops assigned to the route as well as the travel directions to route the buses, metro rail, solid waste carrying vehicles or for logistics.
11	Road Network optimizing	It should have the option to manage network data set properties for travel modes, costs, and route restrictions for traffic management in smart cities.
12	Data Interoperability	Desktop GIS shall support the import and Export of GIS data in various formats for data interoperability.

Table 2 (*Continued*)

Sl. No	Capability	Functional Description
13	Data Model access	The data shall be published on the application server for accessing the GIS data model through intranet or on the internet.
14	Data Modelling	Data Modelling model shall support domains, subtype, spatial rules and relationship, joins and spatial references etc. GIS Solution shall have a GIS catalog/schema to manage and maintain the GIS data modal. It shall support database administration for user creation and management for GIS database.
15	Data Indexing	Features shall support file attachments, which should provide a flexible way to store additional information in any format related to the features on a desktop application.
16	Overlays	Enterprise GIS shall create group layers from multiple data sources including vector overlays on top of raster data using desktop software.
17	On Fly projections	The data creation tool shall support on the fly projections transformation for the coordinates systems of GIS data for matching the projection of GIS data of different projected coordinate system.
18	Time Sliders	Enterprise GIS should have the facility of time slider user interface controls to visualize temporal data.
19	Model Building	Enterprise GIS shall support rule-based Symbology and cartographic representations of map entities. Should support scripting language for customisation.
20	Simultaneous Editing facilities	The data creation activities or the authoring tools by administrators shall support simultaneous editing by multiple users and long transactions capabilities with advanced rule-based editing in industry standard RDBMS.
21	Relational Spatial Data Models	Relational Spatial Data Models shall support data relationship such as one-to-many or many-to-many. the rules should allow users to restrict the type of objects in the origin GIS data, table etc that can be related to a certain kind of object in the destination GIS data, table etc. for integration with different sets of data and information.
22	Audit trailing of Geo-Data Editing	There shall be an audit trail capability for multiple user editing and tracking using multiple set of devices, ERP systems, Databases and APIs. The data base administration in GIS shall have capability for resolving any conflicts that may have occurred due to multiple users editing on data. There should be a complete mechanism for error handling, conflict detection and resolution while submitting the final data to the GIS database.
23	Spatial Analytics	The GIS data creation system shall allow the spatial analytics for generating different thematic information out of spatial and non spatial data integration. The analysis shall pertain to spatial analysis, network analysis, 3D analysis and interoperability.
24	Spatial Adjustment capabilities	The data creation shall have different Spatial adjustment tools including Rubber sheeting, Transformation, Edge matching, Attribute transfer for seamless data integration.
25	Big data Support in data creation	To analyze geospatial records with capability of aggregating points based on proximity. It should support spatial & temporal joins and trends in the cluster of points densities out of the box. System need to be sustainable to handle the load.
26	Animation and space time pattern mining	The spatial analytical capabilities should also support animations and space time pattern mining. It shall provide Artificial intelligence machine learning & deep learning toolsets to support predictive analysis.
27	Integrated Raster Processing	Shall have integrated image processing capabilities
F2	**Web GIS Capabilities**	
28	User Management system	1. Enterprise GIS shall have a portal for the administration that lets administrators add, update, manage and maintain ULB/Town GIS data and user management, Content Sharing and capability to build various GIS applications. 2. Enterprise GIS shall record various service statistics, such as total requests, average response time, and timeouts, and reports this information in the Manager console for better monitoring and performance optimization of services. 3. Enterprise GIS shall be capable of GIS content management (like, manages content locations and marks relevant content as authoritative) and organization user management (for example, user can manage all aspects of inviting and managing user, including adding to groups and resetting passwords) for managing content for different projects and role-based access management. 4. Portal administrator shall be able to create and manage groups out of the box to control access to the maps, applications, and other geographic information. A group owner can decide who can find the group, if others can request to join, and who can contribute their content.

Table 2 (*Continued*)

Sl. No	Capability	Functional Description
		5. Shall provide complete web-based single gateway portal out of the box as an organizational GIS platform to create, access, analyse, manage, and share and disseminate geo-spatial content amongst users for collaborative decision making among the smart city stakeholders. In other words, it should provide a map centric web portal platform for managing the organization's geospatial content. Should have a facility of user management to create an account, and grant/revoke user rights for viewing, publishing or administrator rights to any users across the network. 6. Shall have a facility to share published GIS content with other users and only authorized users can view or modify the shared content. Enterprise GIS system shall have capability to change the web pages appearance (UI/UX), and to select services, base maps, rule based templates, solution galleries and available groups to be used. 7. Enterprise GIS shall allow users to sign in with built-in accounts and accounts managed in multiple SAML-compliant or similar identity providers configured to trust one another to manage users that may reside within or outside your organization. 8. Enterprise GIS shall provide a web publishing wizard so that registered users can publish websites, create GIS applications without the need for programming. Smart City users shall be able to insert search tags to assist authorized users to search and locate geographic information, web maps, and web GIS applications create and shared by other users. The search results shall be helpful to determine the usefulness of each item and find related items. 9. Enterprise GIS shall be capable to display layers dynamically on the map that shall dynamically change based on the visibility of layers, on zoom in and out.
29	GIS Widgets	The Enterprise GIS shall have the feature to web apps using widgets that can easily be configured. The suggestive widgets can be Attribute Table, Coordinate system, Extent navigation, Incident analysis, Scale Bar, Direction, Search, Summary, Temporal Change analysis, Analysis, Base Map Gallery, Bookmarking, Business analysis, Chart Creation, Coordinate Conversion, Distance, Direction, Draw, Data aggregation, Filter, Geoprocessing, Grid Overlay, Measurement, Layer list, Legend, Proximity, Network Trace, Data Reviewer Dashboard, Select, Share, Editor, Print, Visibility.
30	3D streaming and hosting	GIS system should support exporting 3D object layers (Maps/data) files to upload it on the web, where a 3D streaming service is created and hosted. Once published, the resulting 3D scene layer should be viewed or combined with other web layers.
31	Analytical spatial dashboard	Shall enable departmental workflow based analytical dashboard for Communicating the quality of data used in decision-making.
32	WebApps and Maps	Enterprise GIS shall have industry specific templates, apps and maps that can be configured as per the needs of a particular city. These maps, apps and templates shall be based on the industry specific best practices around the globe that can be localized as per city needs for foundational applications.
33	Geoprocessing and Publishing services	The system shall have the capability to process the geo processing on the web where users can use multiple geospatial tools to build models and able to publish the processing service on the web that define the inputs and outputs criteria to come out for the desired analytic results.
34	Web responsive for anytime anywhere access of the smart city data	The web application developed by the Enterprise GIS system shall be web responsive in nature and shall automatically fit to the size of mobile devices. Users shall be able to display maps, get routes and directions, edit and sync data, perform analysis with search & query.
35	Integration of Data from different sources	Enterprise GIS shall be capable to integrate and manage City maps, satellite images, DRONE data, GPS data, LIDAR data, CAD Data of various point of interest information, infrastructure and assets etc. of the city. It shall provide access to free Online 2D, 3D, Street, Base map, imagery Services for location reference on desktop and web.
36	Map viewer for interactive maps	The Enterprise GIS shall provide a map viewer to create, save, share maps and provide analysis tools for clustering, aggregation, proximity analysis, data enrichment, data summary etc.
37	Scalability for GIS performance	Enterprise GIS system shall be scalable both horizontally and vertically. It shall have architecture deployment flexibility such as single machine, multiple machine, cluster-based environment Active-Active, Active-Passive, multiple sites deployment. GIS platform capability should be offered by a single, seamless integration of software based on the same technology.
38	Integrations and OGC compliance	The enterprise GIS shall have open API & SDKs for developers to build/extend custom web mapping applications (for example, Qt, NET, Java, JavaScript). This shall support Open Geospatial Consortium (OGC) and open web services: including Map services, WMS, WFS, WCS, WMTS, WPS, KML, Geo JSON & 3D tiles for the rendering of 3D data.

Table 2 (*Concluded*)

Sl. No	Capability	Functional Description
39	Cross platform support/Platform agnostic	The GIS application server and database servers shall be supported on Windows and Linux platform. Enteprise GIS shall support standard Web server and Application servers like IIS, Apache, Tomcat, Web Sphere, Web logic etc.
40	SOA Architecture	GIS System shall support a Service Oriented Architecture (SOA).
41	Security	The Enterprise GIS shall support Security, Authentication, and Authorization using Web-tier authentication (IWA, PKI and similar), GIS-tier authentication (built-in identity, Enterprise logins and similar) Enterprise Groups (Active Directory and LDAP and Similar) and TLS/SSL.
42	SDKs and Survey Application Frameworks	The Enterprise GIS shall have Software Development Kits (SDKs) to build and deploy native applications on a variety of popular platforms and devices. GIS system shall have out of the box Survey application framework for configuring mobile apps that authority can configure any time to create form centric solutions for the creation, sharing and analyzing surveys as and when required. Enterprise GIS shall help the authority to create/configure survey-based forms that are accessible by city stakeholders/outsourced vendors for field data collection. One should design a survey with predefined questions with logics and easy to fill answers. This should allow embedding audio, images with multiple language offering.
43	Enterprise Wide Platform	Provide Single integrated collaborative Platform based Software which shall support complete workflow for design, development and dissemination of highly accurate spatial Records Information. The solution should support Desktop, Server, Mobile and Cloud Platform.
44	Advanced Geoprocessing capabilities	Shall provide Advanced Geo-processing, Geo-tagging, Geo-coding, Geo-referencing tools.
45	GML-XML	Should enable the GML (simple features) and WFS core standards, and leverage OGC formats such as CityGML, WFS, and KML/KMZ.

4.3.2 *Data Integration*

Data Integration is the core function of a data layer that focuses on integrating sensors, various governmental IT systems and 3rd party IT systems which generate data.

Data is generated by various IoT subsystems, video cameras from various public and private cameras etc, social media data streams, crowd-sourced citizen data, enterprise systems, importing of legacy and/or archived city data, Survey data from LIDAR, GPS, GPR, DRONE, HRSI etc. These systems generate structured data (such as JSON, XML, CSV), unstructured data (such as variable length textual data, device logs), Map related APIs like Google APIs, audio and video data, time-series data, binary data, raster data, point cloud data etc.

Data Ingestion is a sub-function of data integration and shall support a variety of standards compliant data ingestion protocols. Based on the system of concern, the data layer may support real time data ingestion, streaming data ingestion, batch data ingestion or all of them.

In the enterprise GIS system, the data integration shall happen via Service Oriented Architecture, *or* OGC compliance or through REST APIs.

As shown in Fig. 5 the locational data or Geo Events shall be integrated with enterprise GIS via Out of Box systems for electronic devices, or from COTS like KML, Twitter etc. or from GIS Partner systems via sensors, Map services, etc.

4.4 Conceptual Model of Enterprise GIS

Fig. 6 provides a conceptual model of an enterprise GIS for integration and data access in Smart cities. A brief description of different components and sub-systems of the enterprise GIS is given below.

4.4.1 *Web GIS Apps*

The top layers talk about the Apps which are created using API services of data exchange from different sensors, devices and e-Governance applications. The Web GIS Apps may be developed using any of the following approaches:

a) Configure Apps using widgets and templates to meet business needs.

b) Extend existing apps – shall also allow modular frameworks that allow to create custom widgets and plug them into the apps.

c) Customize apps using APIs and SDKs. These APIs and SDKs provide objects like the Identity Manager to manage credentials within custom apps that expose Web GIS capabilities It may be built according to business-focus.

4.4.2 *Automation using APIs and Scripts*

As the volume and velocity of IoT data increases, automation becomes both necessary and more valuable to the business. Automation allows technology to create and maintain infrastructure and programmatically execute the steps of a well-defined workflow while limiting human interaction. Common tools for automation include APIs and scripts.

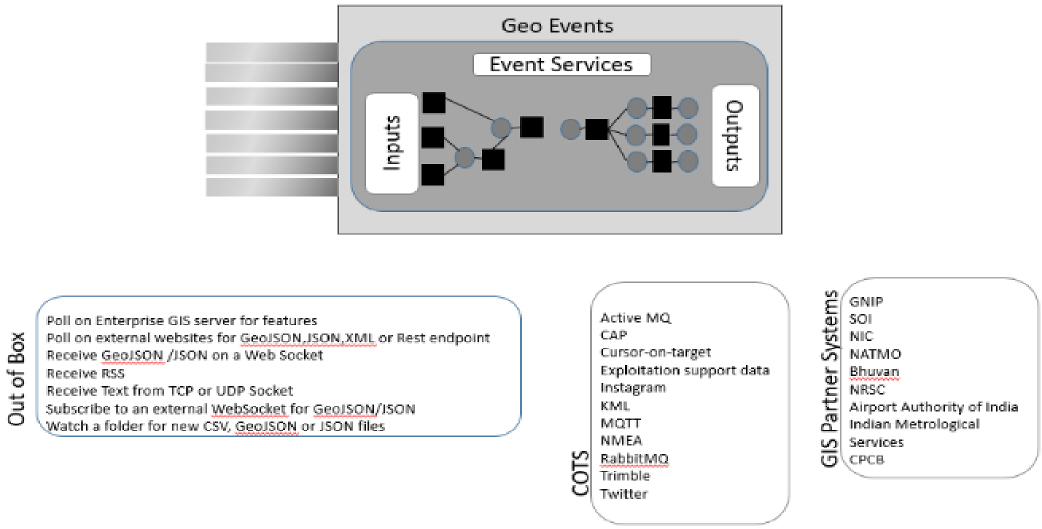
Geo Events
Event Services
Inputs
Outputs
Out of Box
Poll on Enterprise GIS server for features
Poll on external websites for GeoJSON,JSON,XML or Rest endpoint
Receive GeoJSON /JSON on a Web Socket
Receive RSS
Receive Text from TCP or UDP Socket
Subscribe to an external WebSocket for GeoJSON/JSON
Watch a folder for new CSV, GeoJSON or JSON files
COTS
Active MQ
CAP
Cursor-on-target
Exploitation support data
Instagram
KML
MQTT
NMEA
RabbitMQ
Trimble
Twitter
GIS Partner Systems
GNIP
SOI
NIC
NATMO
Bhuvan
NRSC
Airport Authority of India
Indian Metrological
Services
CPCB

FIG. 5 DATA INGESTIONS FROM DIFFERENT SOURCES

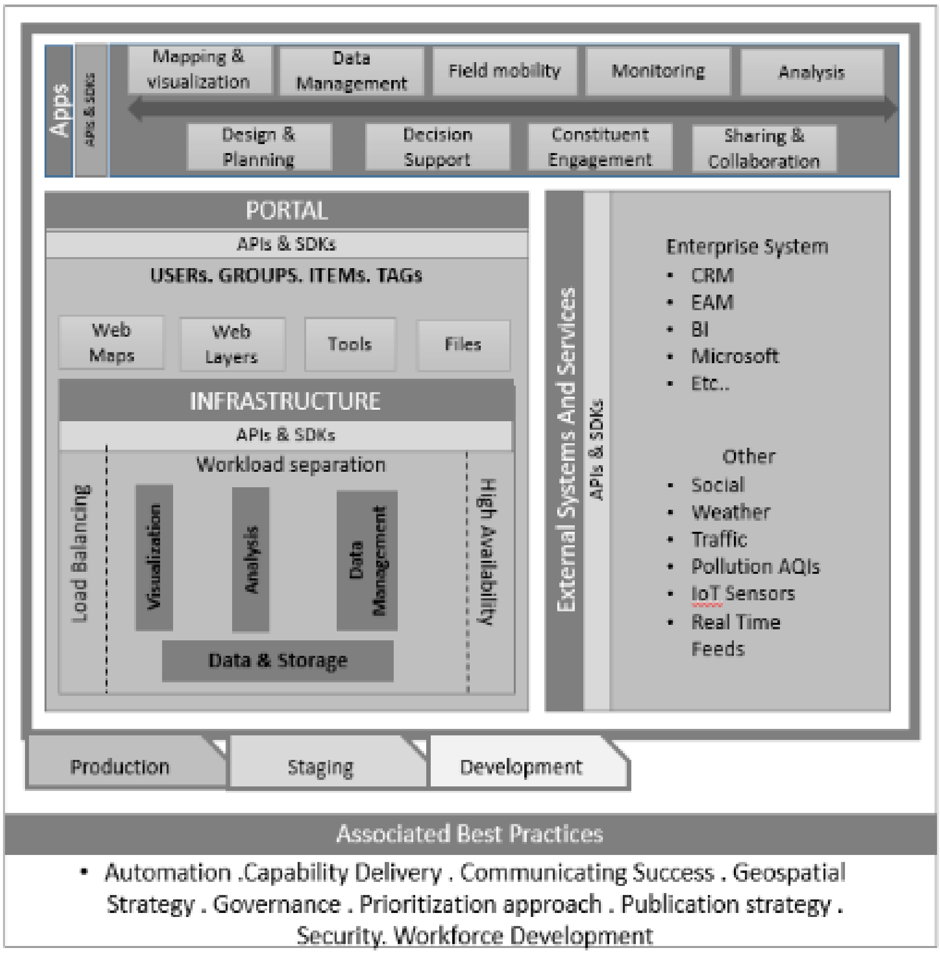

FIG. 6 CONCEPTUAL MODEL OF ENTERPRISE GIS

4.4.3 *Distributed Web GIS*

Distributed web GIS is a modern implementation pattern that supports sharing. It facilitates connection of multiple GIS deployments together, so users from each deployment can share content with others.

4.4.4 *Enterprise Integration*

There may be different approaches to enterprise integration, depending upon the utilization of the data.

a) Geocentric applications, that enhance GIS applications with business data and capabilities to automate or inform location-centric activities.
b) Geoenabled applications, that enhance business applications with GIS data and capabilities to automate or inform business activities.
c) Composite applications, that integrate capabilities from multiple systems in situations where no existing system can or should serve as the hosting framework. This pattern typically uses web services to integrate data and logic from multiple systems to derive new functionality.

4.4.5 *Environment Isolation*

Environment Isolation for production, staging and development should be separated for meeting the SLAs, data safety, and data usage.

4.4.6 *High Availability*

High availability is a set of strategies for minimizing service downtime and maximizing system performance and reliability, because GIS is part of critical business operations and workflows, it is essential for organizations to apply high availability strategies to GIS.

4.4.7 *Data Management*

Data Management exposed as web services that allow end users to create, maintain, and transform geographic data. For example, you can use a mobile app to access a web service for data editing, allowing you to gather location data in the field. Key server-side data management capabilities include short and long transaction editing, data replication, and extract, transform, load (ETL) procedures.

4.4.8 *Analysis*

Analysis represents web services for performing GIS analytics. These analytics can range from simple geometric functions (like point-in-polygon) to complex geoprocessing models for site selection. Analytics can be run on many kinds of data including vector data, raster data, linear networks, imagery, 3D data, real-time data, and big data.

4.4.9 *Visualization*

Visualization represents web services for creating and consuming visual information products like 2D maps and 3D scenes. These products can be dynamically generated on demand, or pre-rendered and cached.

4.4.10 *Data and Storage*

Data and Storage represents the stored geographic information leveraged by GIS servers. Enterprise GIS for Smart cities shall allow multiple storage models for various data types, formats, and uses. There is data store managed by the enterprise applications or through relational data stores (for vector data), tile cache data stores (for map and 3D scene caches), and spatiotemporal big data stores (for big data) Or data stored in spatially aware RDBMS (such as Oracle, Postgres). Or object-relational model for storing geographic data in a relational database management system (such as Microsoft SQL Server, IBM DB2, or Oracle etc), a file-based structure, or an in-memory columnar system like SAP HANA etc. Another model is to connect to externally managed data sources like Hadoop, IBM Netezza, and Teradata or similar.

4.4.11 *Patterns of GIS Usage*

a) Mapping and Visualization is how people understand locations and relationships through visual representations. 2D and 3D (above, below and panoramic) images, maps and charts bring data to life and provide context, so people can share and understand information.
b) Data Management is how people collect, organize, and maintain accurate locations and details about assets and resources. It is important to persist spatial data within storage models optimized for its unique characteristics.
c) Storage models include the geodatabase, spatiotemporal big data store, relational data store, and tile cache.
d) Field Mobility includes managing and enabling a mobile workforce to collect and access information in the field. This improves visibility into the operational aspects of an organization, enhance workforce scheduling, reduce issues caused by stale data, and empower personnel with the information needed to perform tasks while on the move.
e) Monitoring allows people to track, manage, and monitor fixed and mobile assets and resources in real time. This lets organizations tap into, analyze, and display streaming data from many sensors, devices, and social media feeds.
f) Analytics involves applying analytical techniques to transform data into actionable information. Analytics can be used to discover, quantify, and predict trends and patterns to empower decision-making and improve business outcomes.
g) Design and Planning enables people to evaluate alternative solutions and create optimal designs.

This supports the design workflow by enabling users across organizations and communities to collaborate on design decisions.

h) Decision Support involves combining data, metrics, and operational and analytical layers on a map or dashboard to better understand activities, projects, and operations. This produces valuable information for decision-makers.

j) Constituent Engagement includes two-way sharing of information with the public, partner agencies, or other external stakeholders. By improving engagement and collaboration with communities of interest, you can promote more informed decision-making.

k) Sharing and Collaboration provides self-service capabilities, so people can discover, use, make, and share maps. This lets you extend the value of location information to the entire organization or community.

4.5 Enterprise GIS Technical Reference Model

Fig. 7 describes the conceptual technical reference model of enterprise GIS. The reference model is divided into the following three tiers:

a) GIS database and authorising tier for user management,

b) Enterprise GIS application tier for the business processing using the spatial and non-spatial data, and

c) Presentation tier for access by different stakeholders of the smart cities.

The Enterprise GIS shall be integrated with external systems through SOA and Rest APIs.

4.5.1 *GIS database and Authoring Tier*

The foundational tier, the centralized GIS database consists of all the point of interest, spatial and non-spatial layers with operational and analytical store. It consists of Spatial database including GIS data store (Containing the complete data for the Land base, Assets, Smart City Properties, Networks and Urban Services), this also includes other databases received from different departmentssuch as Census, Environment, Socio-economic data that are part of the overall solution. This tier will support the generation of the Smart city geospatial data model. The location based Apps will utilize the data model for GIS data authoring and management. The database integration services will be the mode of connection between the data tier and application tier for data transaction services. The databases are integrating to each other using data Integration Services This centralized GIS database will be utilized by all the Smart City application for their analysis and geo-specific activities. The database tier also includes data authoring stations for the administration and authoring of map data.

4.5.2 *Application Tier*

The Application Tier consists of the server application and Portal providing the necessary functionalities such as authentication, geo-processing, metadata management, map rendering, web application builder, and many ready to use web and mobile applications etc. Application interfaces and applications will be exposed to the clients using these business processing components as specified.

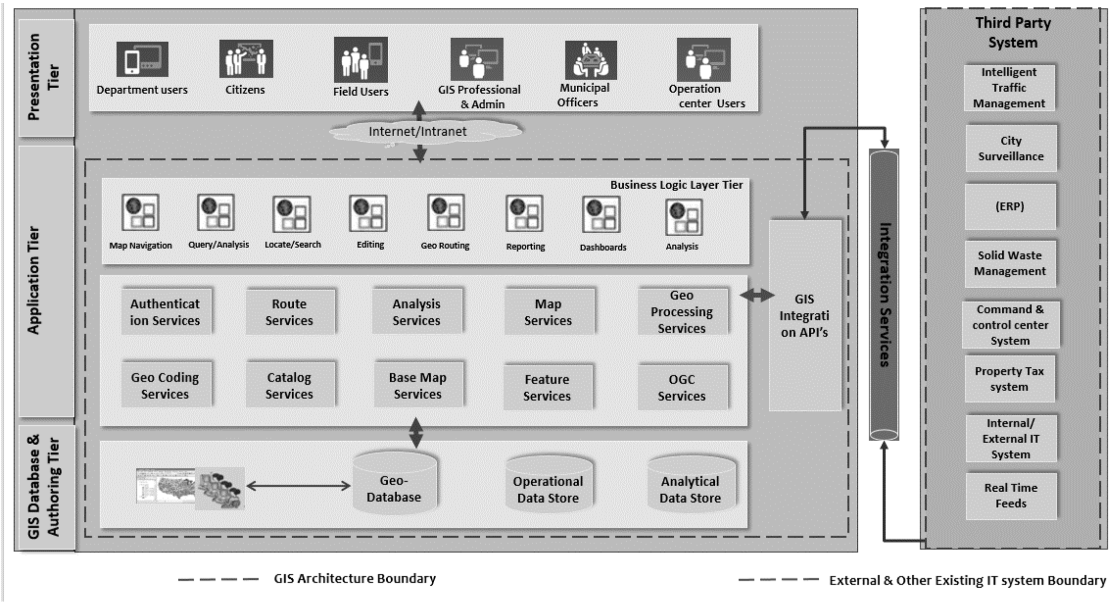

FIG. 7 TECHNICAL REFERENCE MODEL OF ENTERPRISE GIS

4.5.3 *Presentation Tier*

The Presentation Tier interface to be used by authorized stakeholders like citizens, Municipal officials, SPV, utilities, operation and maintenance persons, traffic management authorities, etc. The users will access the data through the intranet or the internet. Authorized users will be able to access the system through multiple interfaces including Desktop, Web and/or Mobile.

4.6 GIS Information Reference Model

Prepare base map of the city which shall be common across all Smart City functions including Surveillance, Lighting, Traffic, parking, ICT based solid waste management, bus transport, Administration, etc. The Base Map of the city shall be prepared at the scale of 1:1000 with Datum: WGS84 and Projection: UTM. For geo-referencing the base maps, there shall be 1 GCP per 5 Sq Kms. The satellite image used for the preparation of the base map shall have a resolution of 0.5 metre (or better) with PAN sharpened Natural Color Composite (NCC).

The Geo Information Reference Model designed should broadly include the following:

a) Geographic features be represented for each theme (for example, points, lines, polygons, or rasters) along with their tabular attributes.
b) Data be organized into datasets, such as feature classes (Vector dataset with certain set of criteria), attributes, raster datasets, and so forth.
c) Additional spatial and database elements be included for integrity rules, for implementing rich GIS behaviour (such as topologies, networks, and raster mosaics), and defining spatial and attribute relationships between datasets.

All the layers shall be captured as. Shp files for easy integration.

Table 3 provides indicative GIS layers for Smart City which shall be displayed on Enterprise GIS portal of Cities and be available for integration with Command and Control Room.

Table 3 Reference Data Model

GIS Layers	Type of Data	Attributes	Requirement
Administrative			
District	Polygon	Name Area LGD Code	Optional
Tehsil	Polygon	Name Area LGD Code	Optional
City Boundary	Polygon	Name Area LGD Code	Mandatory
Municipal Boundary	Polygon	Name Area	Mandatory
Zonal Boundaries	Polygon	Name/Number Area Mohalla Names Zonal Officers	Mandatory
Ward Boundaries	Polygon	Ward Number Ward Corporator: Name, Photo, Mobile number Ward Officers: Name: Phone numbers n Demographic Data: Population, Male, Female, Household, Literacy, Sex Ratio, Population growth, Projected population (Arthmatic method), Geometric Method, (Incremental method) Ward Revenue Ward Expenditure	Mandatory

Table 3 (*Continued*)

GIS Layers	Type of Data	Attributes	Requirement
Village Boundaries	Polygon	Village Name Population	Optional
Plot Boundary	Polygon	Parcel ID Right of records (RoR) Aadhar Number of Owner Type of Use	Optional
Parliamentary Constituencies	Polygon	Nam Area Elected Member	Optional
Assembly Constituencies	Polygon	Name Area Elected Member	Optional
ABD	Polygon	Name Area	Mandatory
Circle Boundary	Polygon	Number Tax Rate Unit	Optional
Planning Boundaries			
Master Plan Layers	Polygon, Line, Point	Landuse Type Landuse Subtype	Optional
City Development plans	Polygon, Line, Points	Landuse_Type Land Use_Sub type	Optional
Landuse Existing	Polygon Line points	Landuse_Type Landuse Subtype	Mandatory
Airport Authority Areas	Polygons	Number Height Clearance	Optional
Eco-Sensitive Zones	Polygons	Sensitivity_Type Area	Optional
Archeological protected areas	Polygons	Type Area	Optional
Health Districts	Polygons	Area Health Officer Number of Facilities	Optional
Police Beats	Polygons	Area Beat Number Number of Police Stations and Chowkis Number of resources.	Optional

Table 3 (*Continued*)

GIS Layers	Type of Data	Attributes	Requirement
Property			
Property Parcel	Polygon	PIN Type Use (Residential, Commercial, Industrial, Public and Semi Public) Address Category Year of Construction Number of Floors Owners name and address Adhar Number Photograph of Property Coverage Area Occupancy Type Source of water Meter Number Fire safety measures Toilet Solid waste management status Tax assessed Status Tax assessed amount Tax Payment status Tax Last Paid Tax CESS Assessed Tax CESS paid Tax Last Paid date	Optional
Transport			
Road with all Hierarchies	Line	Name Hierarchy (NH, SH, Expressway, ODR, DR, V8, BRTS corridor) Road centreline Road edges From and to Length Width Lanes Medians Condition ROW Footpaths Footpath Width	Mandatory
Cycle Tracks	Line	Status (Proposed/Existing) Width Length From-To Smart Bikes available	Mandatory
Junctions	Polygon	Name Types Signalled	Mandatory

Table 3 (*Continued*)

GIS Layers	Type of Data	Attributes	Requirement
Bridges Flyovers Culverts Causeways	Points Points Lines Polygons	Name Year of Construction Scheme Condition Length Load bearing capacity	Mandatory
Metro Lines	Line	Status (existing/proposed) Route ID From-to	Optional
Metro Station	Point	Route No. Station name	Mandatory
Railways	Line	From and to Under Zone	Optional
Railways Station	Polygons	Name Platforms	Mandatory
Airport	Polygons	Name Flights to	Mandatory
Parking Lots	Polygons	Location Occupancy Smart Parking (Yes/No) Type (Paid or Unpaid) Location (Open, enclosed) Ownership (MC/Pvt) CCTV Location in Parking	Mandatory
Rope Ways		Route	Optional
Rope way station		Station name	Optional
Bus Stops	Points	Name Route Smart Bus Stop (Yes/No) PIS available (Yes/No)	Mandatory
Bus Routes	Lines	From and to Length Number of Buses Plying	Mandatory
Traffic Signals	Points	Number Existing or proposed Type of Signals Existing since Working or Not working Source of Power	Mandatory
CCTV Location	Point	Location Type (PTZ, ANPR, CCTV) Status (Existing/planned) Year of Installation Camera Specifications	Mandatory

Table 3 (*Continued*)

GIS Layers	Type of Data	Attributes	Requirement
Utility			
Storm Water Drainages	Lines	Name From and to Length Width Capacity Location on RoW Type of Drain (Open, Closed) Construction Type (Cemented, Kuchca) Elevation Construction Year	Mandatory
Inlets	Points	No. Width Construction Year	Optional
Sewage Network	Line	No. Location on RoW (Left Right middle) From-to Length Width Diameter Type Construction Year Depth	Mandatory
Manholes and Culverts	Point	No. Position Diameter Construction Year	Mandatory
Elevation	line	Contour height	Optional
Treatment Plants	Points	Name Type (Effluent Treatment Plant, Sewage Treatment Plant, C&C Effluent Treatment Plant, Activated Sludge Plant) Capacity Installed Year Condition (working, not working)	Mandatory
Public Conveniences	Points	ID Operated by Type User Type (Male, female, Both) Differentially Abled (Yes, No) Year commissioned Water availability	Optional
Recycled Water	Line	Type Use	Optional

Table 3 (*Continued*)

GIS Layers	Type of Data	Attributes	Requirement
Water Supply System	Lines	No. Location on RoW (Left Right middle) From-to Length Diameter Type (Main/lateral) Commissioned on Depth Flow direction Pressure (designed)	Mandatory
Valves	Points	No. Use Location Type (Stop, Angle, Concealed stop valve, Gate, Ball, Foot, Air relief, Pressure releif, Scour, Gate, Butterfly, Float, Bib cock, Fire hydrant Contruction Year Depth	Mandatory
Pump station	Point	No. Capacity Installed Year	Optional
Over Head Tank	Point	No. Location Capacity SCADA ID Installed Year	Optional
Underground Reservoir	Point	No. Location Capacity Commissioned Year	Optional
Well	Point	No. Location Depth Perineal status	Optional
Public Taps	Point	No. Location Installed Year	Optional
Smart Meter	Point	No. Location CIN Owner Installed Year	Mandatory
Bulk Meter and Flow Meter	Point	No. Location Type (Coriolis Meters. DP Meters. Magnetic Meters. Multiphase Meters. Turbine Meters. Ultrasonic Meters. Vortex Meters.) Installed Year	Mandatory

Table 3 (*Continued*)

GIS Layers	Type of Data	Attributes	Requirement
Electric Substations	Points	No. KVA Commissioned Year	Optional
Electric Network		Line No. From-To Underground/Overground Length	Optional
Street Light Poles	Points	Pole No. Smart Pole Sensors Number of Connections Type of Bulb Installed Year	Mandatory
OFC Line	Line	OFC line No. Installed Year	optional
OFC Manholes	Point	Manhole ID Commissioned Year	optional
Emergency and Disaster			
Earthquake Prone Areas	Polygon	Classification	Mandatory
Flood Prone Area	Polygon	Classification	Mandatory
Cyclone Prone Area	Polygon	Classification	Mandatory
Thunderstorm Prone Area	Polygon	Classification	Mandatory
Lightening Prone areas	Polygons	Classification	Optional
Heat wave prone area	Polygon	Classification	Optional
Cold wave prone area	Polygon	Classification	Optional
Fire Stations	Points	Location Phone number Station head Number of Fire Brigades	Mandatory
Police Stations	Points	Location Type (Thana, Chowki, Police station) Phone number Station head	Mandatory
Flood Sensors	Points	Location	Optional
Fire Sensors	Points	Location	Optional
Education			
University	Points	Name Area Facilities Location Ownership (Govt. Pvt) Levels-(Primary, Secondary, Senior Secondary, Intercollege) Courses	Mandatory
Colleges	Points		
Intercollege	Points		
Schools	Points		
Skill Development Centers	Points		
Vocational Training Institutes	Points		

Table 3 (*Continued*)

GIS Layers	Type of Data	Attributes	Requirement
Health Centers			
Health Centers	Points	Name Type Ownership (Govt. or Pvt. Location) Level Beds Resources Facilities	Mandatory
Blood Banks	Points	Name Capacity	Optional
	Points	Name Location	Optional
Financial Services			
ATM	Points	Location Bank Opening Time	Optional
Banks	Points	Location Bank Opening Time	Optional
Financial Institutes	Points	Location Name	Optional
Insurance companies	Points	Location Name	Optional
Solid Waste Management			
Zones	Polygon	No.	Optional
Smart Bins	Points	No./ID Location Type Address Capacity Sensor Type	Mandatory
Community Bins	Point	No./ID Location Type Address Capacity	Optional
Collection points	Point	Location	Optional
Dumping Ground	Area	Location Area Life	Optional
Plants for Waste processing	Point	Type (Processing Plants, Incinerator and Bio-methanation Plant)	Optional
Weighing Bridge	Point	Location	Optional
Routes of waste collection	Line	No. No. of vehicle Plying	Mandatory
Fuel Stations			
Petrol Pumps	Point	Location Owned by	Optional

Table 3 (*Continued*)

GIS Layers	Type of Data	Attributes	Requirement
Market Places			
Whole sale	Point	Location	Optional
Shopping centers		Specialty	Optional
Shop		No. of establishments	Optional
Hat Bazar			Optional
Malls			Optional
Public Services			
Cremation ground	Point	Location Type (Burial place/Grave Yard/Creamtion ground) Type of Facilities Available Capacity	Optional
Post Office	Point	Location	Optional
Community Hall	Point	Location Booking Details	Optional
Kiosks	Point	Location Owner	Optional
Government Offices/Buildings			
	Points	Name Central/State/Local Offices List	Optional
Religious			
Temples	Point	Location Name	Optional
Mosques	Point	Location Name	Optional
Gurudwaras	Point	Location Name	Optional
Churches	Point	Location Name	Optional
Residential			
Hotels	Point	Location Name	Optional
Others	Point	Location Name	Optional
Tourism and Recreation			
Spiritual	Polygon	Name	Optional
Historical	Polygon	Details	Optional
Recreation Centers	Polygon		Optional
Parks and Gardens			
	Polygon	Name Area Available facilities	Optional
Restricted Areas			
Defense	Polygon	Name Area	Optional
Others	Polygon	Name Area	Optional

Table 3 (*Concluded*)

GIS Layers	Type of Data	Attributes	Requirement
Smart Integration			
Proposed Smart Traffic light points	Point	Location	Mandatory
Smart Pole	Points	Location Sensors Lighted Type of light Working Status	Mandatory
Bike Sharing	Area	Location	Mandatory
VMS	Point	Location	Mandatory
Emergency Boxes	Points	Location	Mandatory
Cameras	Points	Location Camera Number IP Address	Mandatory
SCADA	Points	Location SCADA ID	Mandatory
Sports			
Stadiums	Area	Location Name	Mandatory
Playgrounds	Area	Location Name Area	Optional
Urban Poor			
Slums	Area	Name Population Households No Household with LPG Household With in Premise Water Supply Household with In Premise Toilets Household with Electricity Demographics Household having waste management Facility	Optional
Services for Urban Poor	Points	Name Type (Education, Health, Shops etc) Maintained by Condition	Optional

NOTE — The mandatory layers are essential for smart cities and opetional layers are “good to have”. IS 18000 : 2020 capture the Base map requirments of a smart city which are in real sense the mandatory layers.

The Information Reference Models shall have defined Schemas and Taxonomies, which are spatially connected and follows topological rules and also Attributes and Relationship Rules. It shall have a version management and archiving facilities. The Rules are to be defined for Polygon, Networks and Points defining Spatial Joins and relationships. The data model shall have validation Rules with domains and subtypes, design workflows and map properties, Label and Annotations classes, network dataset design & rules and tools for Enterprise wide base map creation and updation. It shall be directly used in the Applications.

ANNEX A

(*Clause* 4.2)

USE CASES

A-1 TRAFFIC MANAGEMENT SYSTEM

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
Location of the Traffic Signals. The location of Junctions. The location of CCTV cameras on Junctions.	The Departmental Integration will help in further expansion of the GIS layers like integration with Traffic data with GIS may help in generation of Travel demand, the Volume by capacity of the roads, the identification of traffic bottlenecks, the accident prone areas. GIS enabled maintenance workflow e.g. number of potholes on defined road stretch. Generate Department wise spatial queries and output.	Video Feed of Traffic through ATC controller and link with Traffic management server in ICCC to visualise the live traffic conditions in the city and the traffic management. It will generate a hotspot of traffic in real time and the alternate diversion. The time wise analysis of the records will show different type of analysis: Peak hour traffic. Traffic accumulation causes. The traffic delays. This may then be used for modelling Traffic management plan of the city.

A-2 SAFE CITY CAMERAS FEED

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
Location of the Surveillance Cameras in the City. Location of the Police Beat maps. Location of Police stations and Chowkis.	The coverage areas of the cameras. The Police beat maps with further details of the resources like Thana’s Chowkis etc. Resource deployment at each beat, Patrolling routes. Number of vehicle deployed. Location details of criminals operating in area Generate Department wise spatial queries and outputs.	The dynamic integration with the protocols of the Cameras. Live feed of a camera can be launched from the map. The analysis involves Hot Spots of Crime, incidents and Accidents, different type of clustering of type of incidents. The patterns of Incidents, Dashboards with spatial analytical data.

A-3 EMERGENCY RESPONSE AND DISASTER MANAGEMENT

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
The mapping of disaster prone areas in the city. The location of all the Disaster Management related Layers like hospitals, police stations, Fire Brigade, Disaster Control Rooms, Disaster control authorities with details, Shelter Sites, Location of critical Assets, location of transport depots	The Departmental integration will help in creating a resilient City framework like the different types of disasters expected in the city and it's impact, over lives and properties. Using Weather Updates for Cyclones, Thunderstorm, Lightning, Heat wave, Cold wave, Heavy Rainfall/Snowfall etc. and updates for air quality, flood management related to these events and Alert generation for People through Apps, Media, Display and Public announcement systems. Workflow for Alert generation to requisite authority for taking actions. There should be integration of data from MoES with the GIS and web GIS platform as well as mobile App for all purposes and all stakeholders including citizens, Govt and non-govt agencies etc. The location of Vulnerable Critical infrastructure and Vulnerable social groups will be identified as part of disaster prevention. In the incidents of Disaster, the GIS system may be used in a crowd sourcing workflow management system to identify location of disaster. The workflow may further generate alerts and triggers for the respective authority. Social Media linkages with GIS for Live data on Disasters and for rapid analysis and decision support system including: 1. Shortest Path to reach the Disaster prone site. 2. Evacuation Plans. 3. Nearest Hospital. 4. Food Dropping. 5. Public Alerts. 6. Route for water tankers. 7. Critical Asset Restoration plan using GIS. 8. Spread Mapping of disaster. 9. GIS based Critical Asset protection plan.	The analysis of the Disaster related data for the long term Disaster prevention plan like flood management strategy, Fire safety Management system, Accident management system, Health emergency Management, Relocation plans, Decongestion plans. The climate weather data stored over a period of time can be used for Meteorological analysis and representation over map. Like, 1. Extreme and Average rainfall in the city and Drainage Carrying capacity. 2. Temperature Range and the Green building management plan. 3. Pollution Concentration and Diffusion models. 4. Pollution and Health Models. 5. Integration with VMS for Alerts. Predictive analysis of different type of disasters. Integration with VMS for Alerts.

A-4 METEOROLOGICAL DEPARTMENT

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
Weather Update on the city map. Pollution Update on City map.	Using Weather Updates for Flood Management and Alert generation for People through Apps, Media and Public announcement systems. Workflow for Alert generation to requisite authority for taking actions.	The weather data stored over a period of time can be used for Meteorological analysis and representation over map. Like, 1. Average rainfall in the city and Drainage Carrying capacity. 2. Temperature Range and the Green building management plan. 3. Pollution Concentration and Diffusion models. 4. Pollution and Health Models. 5. Integration with VMS for Alerts.

A-5 DYNAMIC MARKET PLACE

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
Dynamic Market Place location and routes.	The departmental integration provides the data related to the Dynamic market places. And generate spatial queries about the day of visit in particular locality, the frequency and duration of visit, the type of commodities available.	Integration with GPS and Tracking Location of the Express. It will be integrated with the call centre for the query for the products. It will have interface with Web and mobile GIS application. The data stored may be utilised to analyse the demand analysis, buyers preferences, the demographics of buyers, the location analysis in terms of effectivity and Business GIS solution.

A-6 SMART PARKING

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
Location of the Parking open Parking, Multi-Level Parking and Closed Parking with Capacity.	The departmental integration will provide the details with data like, timings, Rate cards, the maintenance authority, the duty allocation etc. Geo-fencing for parking nearby.	The real time integration will generate a geo fencing with proximity to parking and availability of space. For Bay parking management using sensors. In long terms this will be helpful in analysing the adequacy of parking facilities in the city.

A-7 PUBLIC BIKE SHARING

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
Location of Bike docking Stations and number of bikes available at each of the location.	The demarcation of the Byke routes and it's details.	Real time bike availability status over the map. Analysis of Adequacy in compare to demand. The number of users, the areas where the usage is high. The low usage area and reasons for it. The User details, like age group, economic status, gender etc. for future planning of byke routes.

A-8 SMART POLE & SMART LIGHTING

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
Location of Smart Poles with all the facilities (sensors) available on it along with pole numbers.	The departmental integration for the spatial queries and work flow of maintenance. The asset details of the poles. The number of houses connected with the poles. Street Light Type.	Dynamic Status of the street Light (working or not). Wi-Fi Hot Spot Coverages, real time integration with digital signages. Real time environmental conditions like concentration of pollution at particular points. Asset management of Poles. Pollution Plume analysis using wind direction as dynamic factor.

A-9 SOLID WASTE MANAGEMENT SERVICES

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
Location of the Primary, Secondary and Tertiary Waste Disposal Sites along with data of capacity, frequency of pickup , maintained by etc. Route map of the waste collection vehicles of different types.	RFID tagging of waste bins and real time update of waste lifting by the sweeper from the houses. GPS based Vehicle tracking system of waste carrying trucks and vehicle with integration with way-bridge. Integration with Event Management of the city for waste collection rerouting.	Data will be analysed for total amount of waste generated from each location, type of waste, recyclable waste per location. And optimization of landfill capacities. Optimization of the routes of the waste carrying vehicles. Integration with Waste Bin Sensors and Alert of Pickup.

A-10 INTELLIGENT TRANSPORT MANAGEMENT SYSTEM

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
Location of All the Transport hubs in the city, including Bus terminus, Bus Depots, truck terminus, Taxi Stand, Auto Rikshaw stand, Rikshaw stand. Location of Bus Stops.	The intelligent Transport System integration with departments will give details of Bus routes, Details of fleet management and crew Management. The complete transportation system including the last mile connectivity. The areas selected for NMT. The spatial queries of the department.	Automated Vehicle Tracking system showing the Bus's destination and expected time of arrival at the destination. Geo-fencing for Bus Arrival Alert. The fleet management system provides a lot of data related to commuters. A GIS based commuter demand analysis, can be undertaken providing better fleet management and optimising the fleet on routes. The speed delay system helps to define the alternate route of the buses.

A-11 MUNICIPAL CORPORATIONS CALL CENTRE & MUNICIPAL CORPORATIONS SERVICES

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
Geo location of the Distress Call Maker.	Integration with CRM. Analysis of type of calls, time of calls, distress type, location wise distress calls. Create Dashboards.	The call data can be segregated as per type of calls, the callers, the false calls, the call response time, the efficiency in solving the distress. This increase the efficiency of the Civic bodies.

A-12 DIFFERENT TYPE OF APPS

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
	Creation of Workflow for field crews of different departments.	Collection of the Data from the apps for different level of anaysis and report generation, like alerts and number of people registering for these apps. The dashboards. The analysis of the use of the Apps.

A-13 WATER MANAGEMENT SYSTEM

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
Map of the entire water distribution network from Booster pumps to individual connections at house hold level. DMA Mapping.	1. GIS based Asset Lifecycle Management of the water supply network and generation of Alerts. 2. Mobile GIS integration and alert system for the field crew for maintenance and operation of the assets. 3. The assessment of water demand from locations and optimization of the water supply based on this. 4. The water quality assessment reports. 5. The Revenue generation vs. expenditure on asset management location wise. 6. The locational analysis of breakdowns. 7. The per capita water usage and wastage analysis. 8. The analysis of the budget on Network, creation, extension and O&M. 9. The analysis of project status. 10. Dashboard of Performance.	SCADA integration for real time update on water pressure, flow and network problems. Integration with Smart Meters for revenue collection. The data collected over a period of time will help in analysing the causes of Non Revenue and take decisions accordingly.

A-14 DIAL 100

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
Location of all the police station and chowkis with the list of police personnel and the vehicle details.	The Automated Call registration in the call center and Computer aided despatch system based on location of the GPS enable patrolling vehicles and defining root to the crime locations.	GIS based analysis and intelligence related to the calls, the type of crimes, the average response time, the rate of crime prevention, the crime hotspots and crime pattern analysis and trend analysis.

A-15 DIAL 108

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
Loaction of all the health centers and health centers with ambulance facility and proximity analysis.		The Automated Call registration in the call center and Computer aided despatch system based on location of the GPS enable vehicles and defining shortest route to reach the hospital facility. It may also be related to the automated green light for creating green corriders in situation of major disasters or incidents.

A-16 ELECTRICITY

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
Map of the entire electricity distribution network till consumer level. This shall include all the network components, as well as substation locations and drawings attached to it.	1. GIS based Asset Lifecycle Management of the electricity network and generation of Alerts. 2. Mobile GIS integration and alert system for the field crew for maintenance and operation of the assets. 3. Different type of network analysis like load distribution analysis. The analysis of the budget spend on infrastructure creation, extension and maintenance. Analysis of Project status	SCADA integration for real time update on availability and network problems including the voltage drop, tripping, outages etc. The SCADA integration will also support the Smart Grid management as per real time demand and supply of power 1. Integration with Smart Meters for revenue collection. The assessment of power demand from locations and optimization of the supply. 2. The power infrastructure assessment. 3. The Revenue generation vs. expenditure on asset management location wise. 4. The locational analysis of breakdowns. 5. The per capita power usage 6. The T & D lossess analysis location wise.

A-17 EDUCATION

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
Map of all the Schools in the city with proximity query and buffer query.	The analyis of the Students teachers ratio, the analysis of the Students Gender, the analysis of the school infrastructure, including drinking water and Sanitation status. The analysis of the performance of the schools based on a set of parameter. The analysis of the budget.	The integration with the cameras in the government school to monitor the real time school education status. The real time integration of the school helps to generate reports on students and teachers attendance. The GPS integration with the school buses will generate the report on speed delay, driver behaviour.

A-18 HEALTH

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
Location of all the health centres in the city-hospitals, dispensary, Super speciality hospitals, blood banks, clinics, with specialities, all the medical stores, proximity query, accessibility analysis and buffer query.	The Departmental Integration will give a status of different types of information spatially like number of patients registered per day, the ratio of doctor and patients, the infrastructure details, the specialities etc. The locational data to be assessed in analysed in terms of patients inflow, health facilities demand analysis, the resource adequacy analysis. This will support in allocation and reallocation of health facilities and resources. The analysis of the budget.	The integration with the cameras installed in the government health centres to monitor their operations in real time. In long run the footfall will be analysed for the management of the patients in hospitals.

A-19 INTEGRATION WITH CROWDSOURCING DATA

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
		The data can be analysed in terms of public opnion and mood and participation on different issues related to the city planning, administration and management.

A-20 INTEGRATION WITH FIRE BRIGADE CONTROL SYSTEM

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
Location of fire station with facilities. Location of Fire Hydrants.	The departmental integration may produce the spatial reports like the Fire Brigade at each location, Utilization of the Fire Brigade, crew at each location, coverage of the Fire stations etc. Budget allocation and utilization.	Real time integration with the fire service vehicles and shortest route analysis and two way communication Analsysis of the location data in terms of time to reach, the alternate routes and number of Fire Brigade serving the population as per norms.

A-21 GREEN BUILDINGS

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
Location of buildings with Water harvesting and solar roof tops and energy management practices.	The analysis of the data will help in assessment of the trend of the green development in the city and the pattern analysis in relation to the demand.	

A-22 KIOSKS

GIS Integration Level 1 (Visualization layers over Portal for Use by stakeholders	GIS Integration Level 2 (Integration with Department)	GIS Integration Tier 3 (Data Analysis reporting and Intelligence)
Location of the Kiosks in the city.		Analysis of the coverage of population. Type of people accessing the kiosk, the service wise categorization in the Kiosk. Future demand analysis of the new Kiosk.

ANNEX B

(*Foreword*)

COMMITTEE COMPOSITION

Smart Infrastructure Sectional Committee, LITD 28

Organization	*Representative(s)*
Indian Institute of Science, Bengaluru	Prof Bharadwaj Amrutur (***Chairman***)
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Shrama Technologies Pvt Ltd, Bengaluru	Mr Amarjeet Kumar
Treasure Data	Mr Kumaar Guhan
Amravati Smart City Development Corporation Limited, Mumbai	Mr Siddharth Ganesh
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Siemens Limited, Mumbai	Mr Manoj Belgaonkar Mr Ravi Madipadga (*Alternate* I) Mr Pradeep Kapoor (*Alternate* II) Mr Vikram Gandotra (*Alternate* III)
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Hexagon	Mr VinayBabu Adimulam

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22 OGC Keyhole Markup Language (KML).

23 Indexed 3D scene layers (I3S) for streaming 3D BIM data.

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This Indian Standard has been developed from Doc No.: LITD 28 (17250).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Published by BIS, New Delhi